WECC Wind Generator Modeling

(a collaboration of WECC, CEC, and NREL)

Transmission Research Program Colloquium

CALIFORNIA ENERGY COMMISSION
1516 Ninth Street
First Floor, Hearing Room A
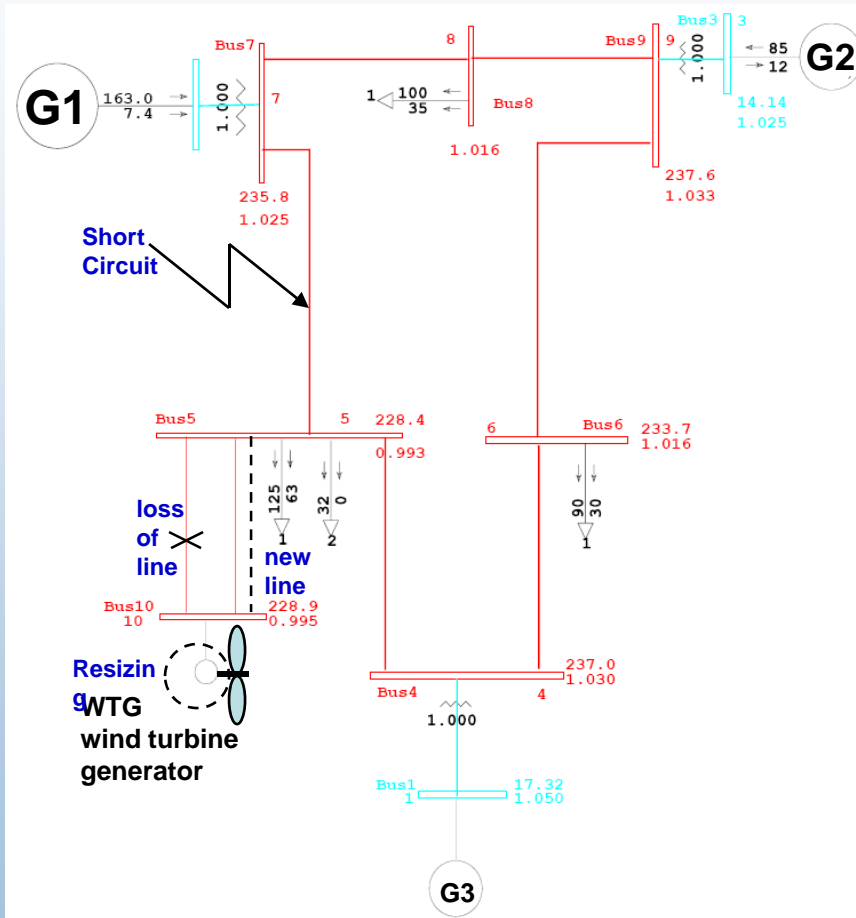**Sacramento, California**

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Background

(Dynamic Model of a WTG)

Transmission planners, operators, wind plant developers, turbine manufacturers, utility engineers, researchers, and consultants use dynamic models to study the dynamic behavior of power system.

- To study the impact of the wind turbine generator (WTG) on power system and vice versa (i.e. to keep voltage and frequency as stable as possible for customers connected to the grid).

- To study the impact of expansion, reduction, and outages: transmission line, transformer, switch gear, generator, new wind power plant, repowering or resizing wind plants, and additional reactive compensation.

- To study the reliability of a power system during transient events such as loss of line, loss of load, short circuits, loss of generation, loss of wind, and voltage ride through of generators, etc.

NREL National Renewable Energy Laboratory

Background

- Urgent need for WTG dynamic models to accurately represent modern WTGs and to expedite wind deployment (tools for transmission planners, wind plant developers, and wind plant operators).

- In the competitive world, turbine manufacturers developing new technology are compelled to protect proprietary information embedded within WTG dynamic models.

- Mandatory NERC Mod 12, 13, 14 standards require the availability of acceptable (validated, standard library/non-user written, and non-proprietary) dynamic models to reliability entities (WECC and others) for power system planning.

- WECC, CEC, and NREL as public institutions to join forces and develop generic models of WTGs for power system planning to bridge the gap between the planners and turbine manufacturers.

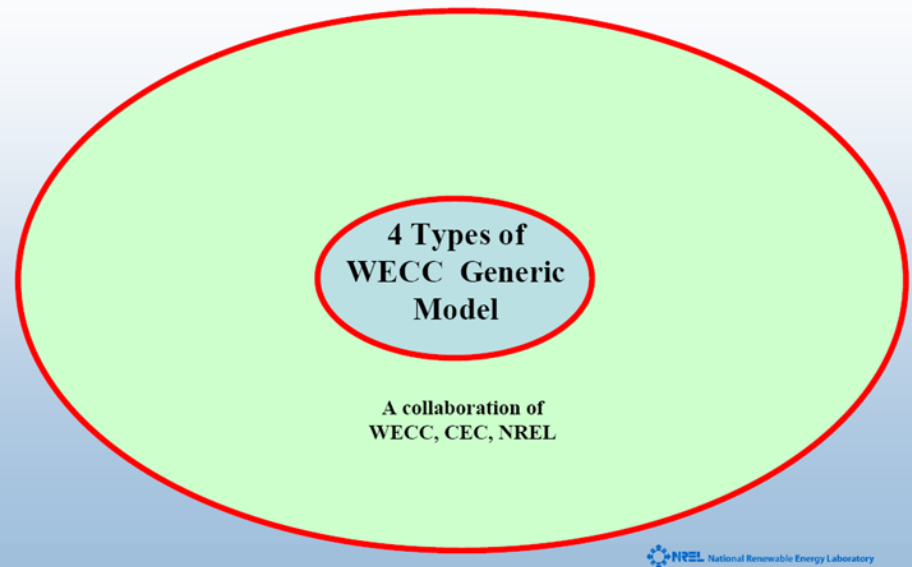- Alliances have been formed among WECC, AWEA, IEEE, UWIG, and other international organizations.

Background
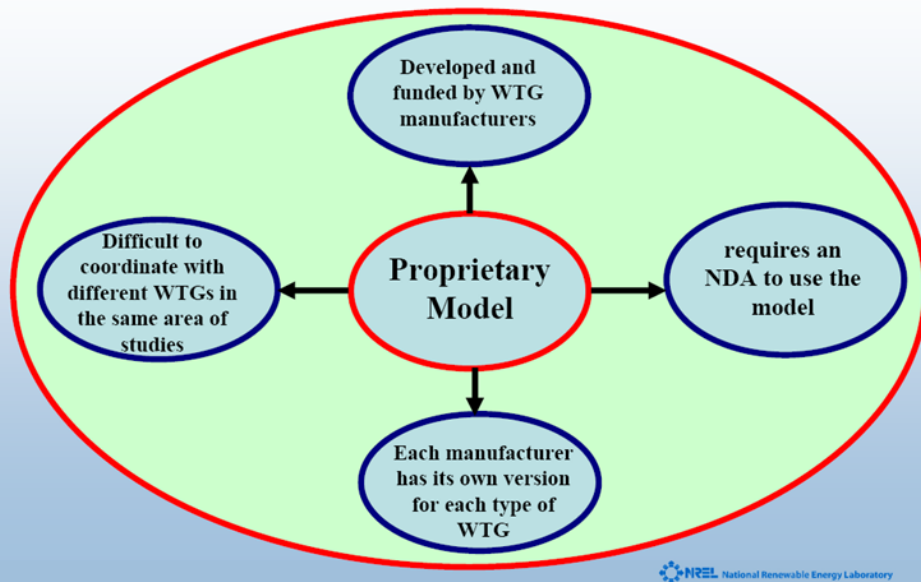
Note:
NDA = non disclosure agreement

Purpose of Research Project

- To develop and validate generic, non-proprietary wind generator dynamic models for transmission planning and other studies.

- To develop power flow and dynamic modeling guidelines for wind power plants.

Overall Project Benefits

- **Capital cost benefits:**
  - With the potential of $10 B+ investment in wind energy by 2010, and the potential of 20% wind by 2030 for the U.S. grid (> 300 GW wind), the stakes are high when designing the infrastructure to accommodate additional wind energy to the CA and national grid.
  - A validated model should be used for system impact / transmission expansion studies (to identify major system upgrades and the cost associated with those studies).

- **Reliability benefits:**
  - With a 5.4 GW potential wind development planned for CA, and > 300 GW nationwide, invalid models can lead to inadequate infrastructure, thus jeopardizing the reliability of the power system.

- **Increased integration of intermittent resources:**
  - The correct assessment of the grid condition can lead to a realistic and increased integration of renewable resources into the power grid.
  - With the availability of wind turbine dynamic models, a wider audience will be able to perform wind interconnection studies in the public domain without the need for the nondisclosure agreements.

- **Availability of the generic dynamic models:**
  - Saves time and funding from developing multiple turbine models by manufacturers.
  - Benefits the utilities, developers, TSOs, and consultants from having to develop NDAs with multiple manufacturers and deal with incompatible dynamic models.
  - Expedites the process of getting access to dynamic models for engineers and researchers in industry, university, nationwide, and worldwide, thus moving the technology and R&D at a faster rate and wider involvement.

Wind Generator Generic Model

- WECC Generic Wind Generator Dynamic Models:
  - 4 different types of WTG
  - Non proprietary
  - Written in Power System Simulator for Engineers (PSS/E) and Positive Sequence Load Flow (PSLF) simulator platforms; the two major power system simulation tools in the United States.
  - WECC task force with NREL collaboration produced specifications, test procedures, and validation procedures for all 4 types of WTG.

- Siemens PTI has completed the generic dynamic models for Type 1, Type 2, Type 3, and Type 4 (prototype) in PSSE.

- GE has completed the generic dynamic models for Type 1 and Type 3 in PSLF, and is currently working on Type 2 and Type 4.

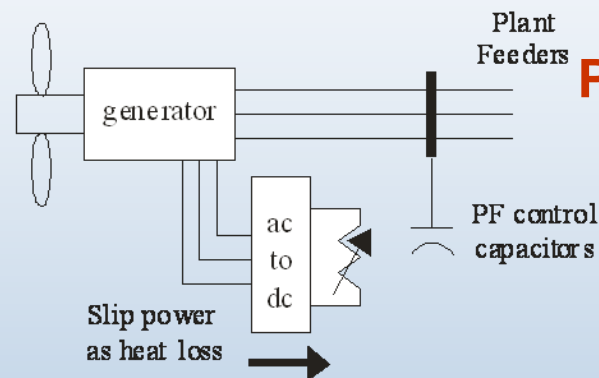# Four Different Types of Wind Turbine Generators

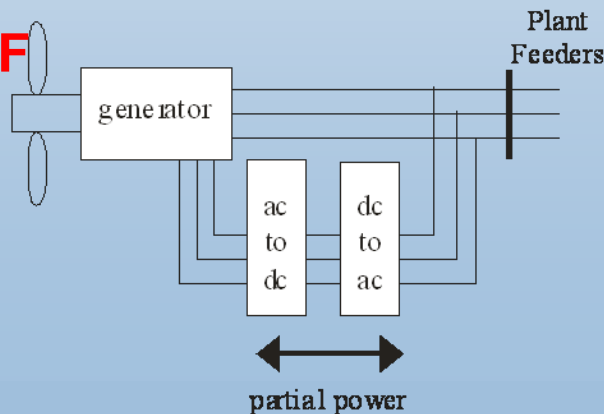

Type 1

Type 2
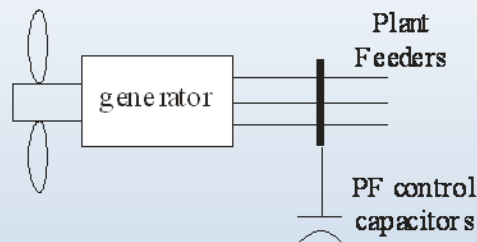
PSSE/PSLF available
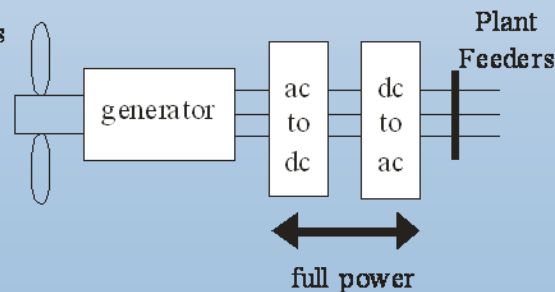
PSSE available

PSLF to be completed

Type 3

Type 4

PSSE/PSLF available

PSSE prototype available

PSLF to be completed

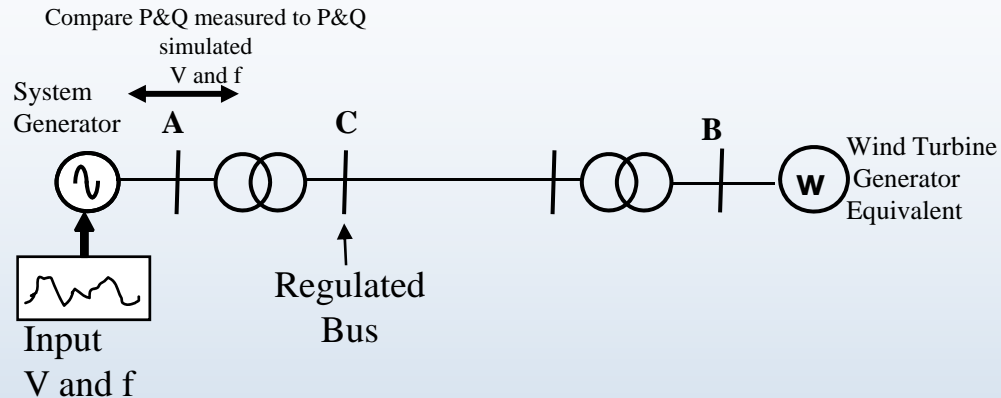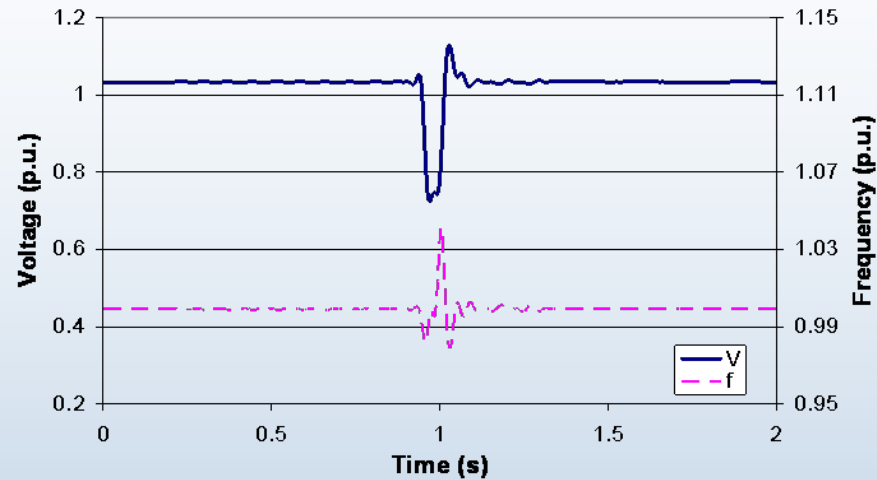NREL National Renewable Energy Laboratory
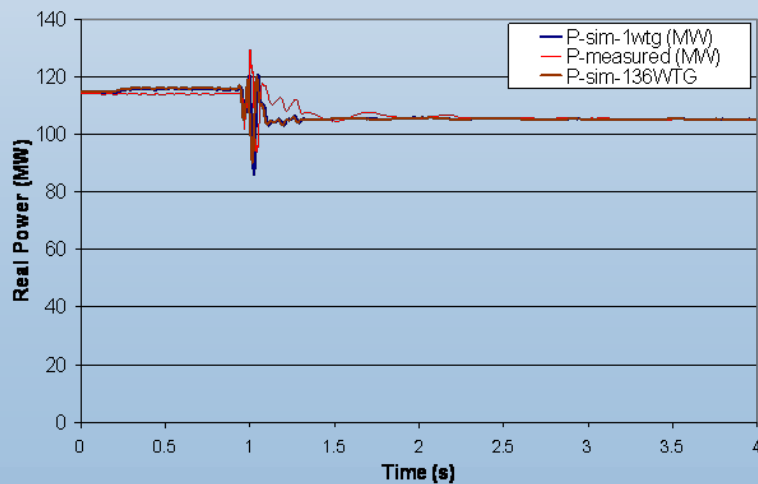
Validation of Dynamic Model

- Different types of validation of Dynamic Models against:
  - Field data measurement
  - PSLF/PSSE proprietary dynamic models developed by turbine manufacturers
  - PSCAD dynamic model (commonly used to simulate detail/complete models of generators, power converters, and FACTS devices for transient studies).

- Field data – Type 3 model validated against field data measured at the PNM wind power plant.

- PSLF/PSSE proprietary dynamic model development is underway (collaboration with University of Michigan – Ann Arbor).

- PSCAD dynamic model development is underway (collaboration with University of Texas – Austin).

Validation of Dynamic Models

V and f

Compare P&Q measured to P&Q simulated
V and f

System Generator   A   C   B   Wind Turbine Generator Equivalent

Input V and f   Regulated Bus

Real Power Comparison

Reactive Power Comparison

NREL National Renewable Energy Laboratory

Wind Power Plant "Equivalencing"

Individual WTGs and turbine-level reactive compensation (if any)

POI

Power Grid

Station transformer & plant-level reactive compensation (if any)

Collector system with several overhead and underground feeders
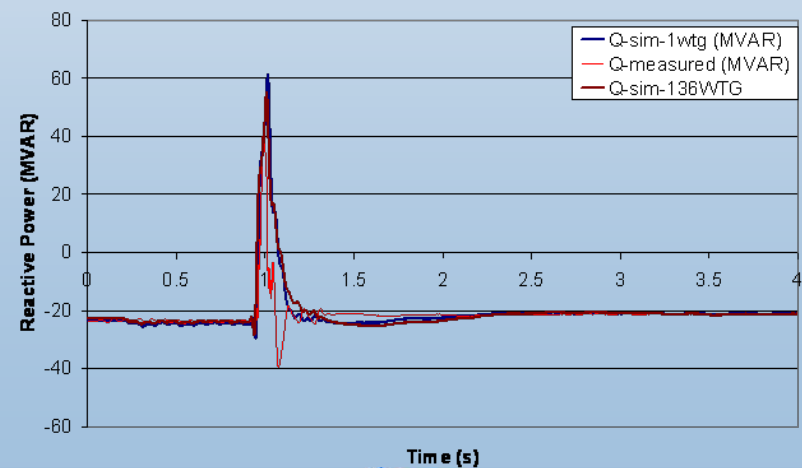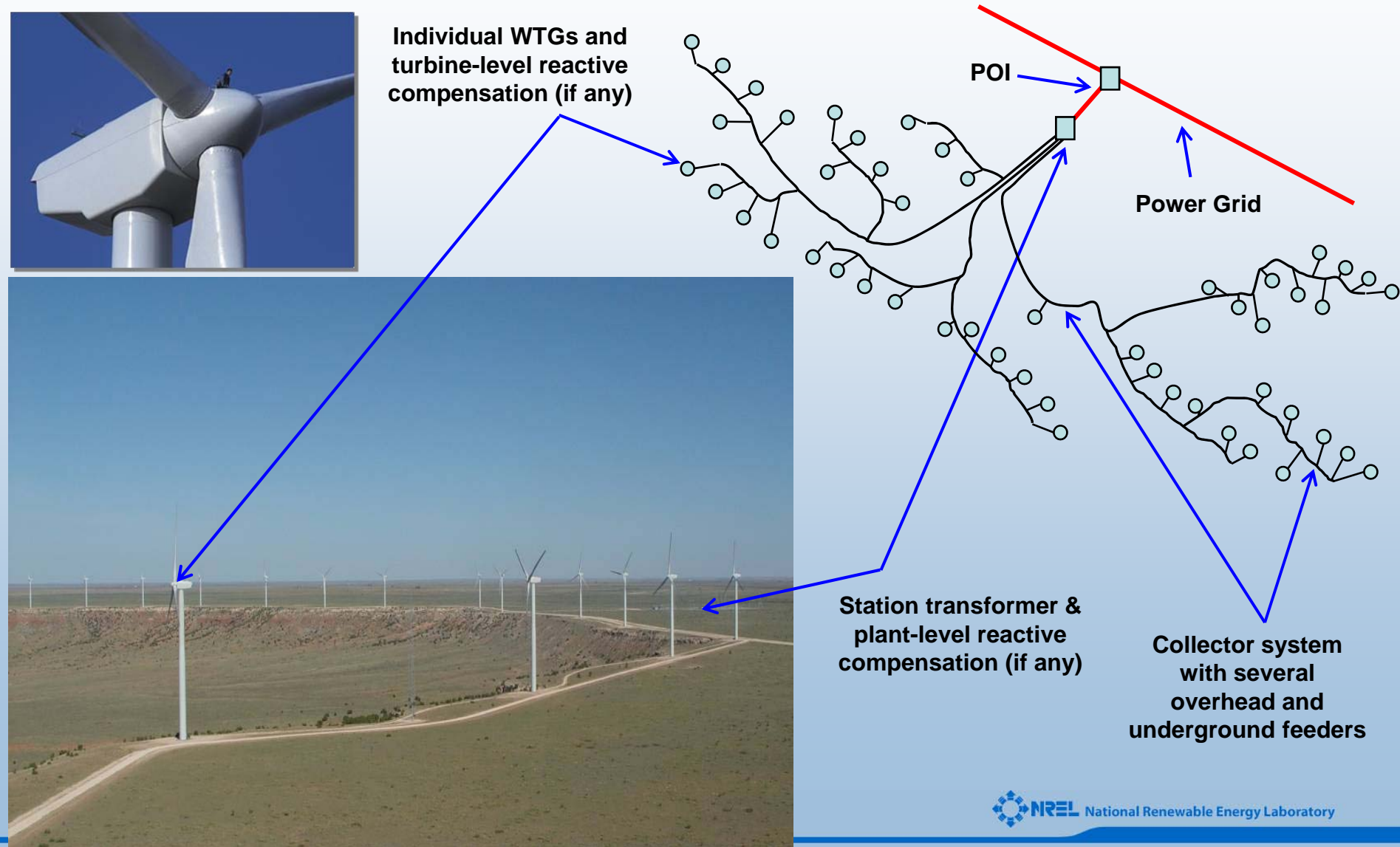
Wind Power Plant Equivalencing

(Type 3 WTG)

Interconnection Transmission Line   **Station Transformer(s)**   **Collector System Equivalent**   **Pad-mounted Transformer Equivalent**

POI or Connection to the Transmission System

(W) 91% WTGs stays "on" after the fault.

Two-Turbine Representation

(W) 9% WTGs were dropped of line during the fault.
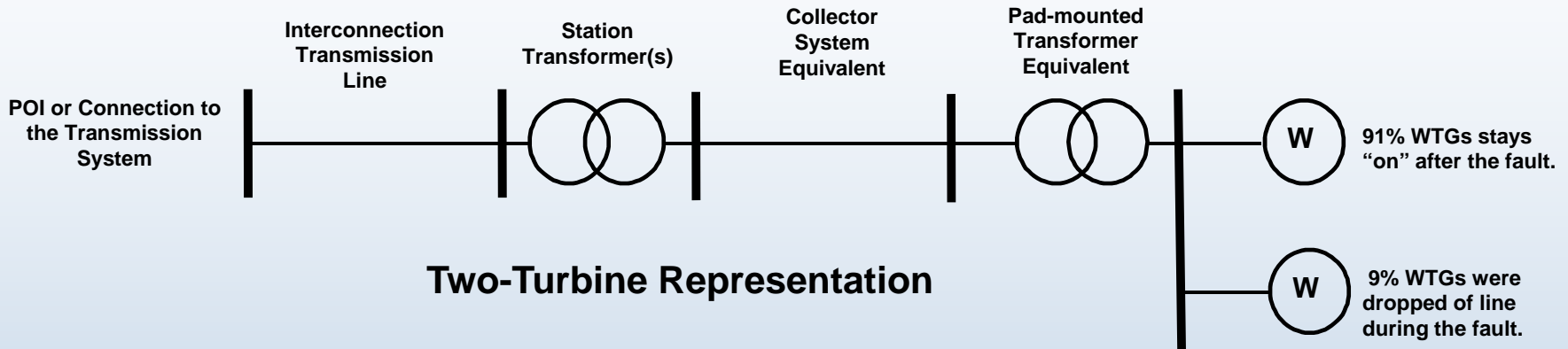
Complete Representation (136 turbines)

Interconnection Transmission Line   **Station Transformer(s)**

POI or Connection to the Transmission System

136 WTGs were represented

9% WTGs were dropped of line during the fault.
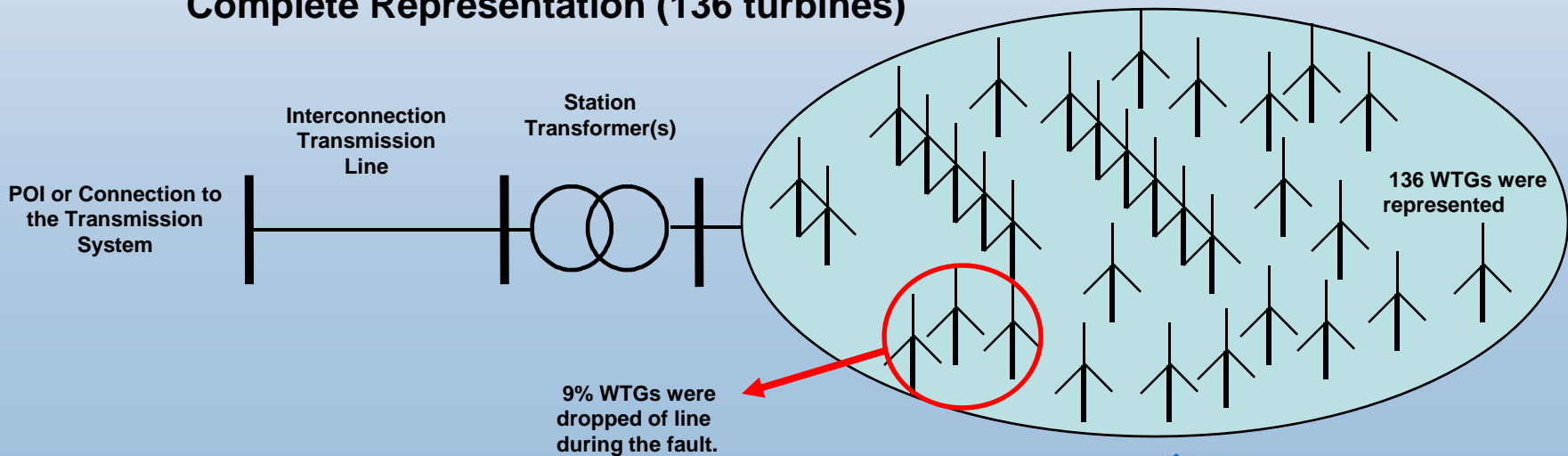
Wind Power Plant Guidelines

- WECC Power Flow Guidelines for Wind Power Plant (**<u>completed</u>**).

- WECC Dynamic Modeling Guidelines for Wind Power Plant (**<u>underway</u>**).

List of Related Publications and Tutorials

- A. Ellis, E. Muljadi, "Wind Power Plant Representation in Large-Scale Power Flow Simulations in WECC," presented at the IEEE Power Engineering Society, General Meeting, Pittsburgh, PA, July 20-24, 2008.

- E. Muljadi, A. Ellis," Validation of Wind Power Plant Dynamic Models", invited panel presented at the IEEE Power Engineering Society, General Meeting, Pittsburgh, PA, July 20-24, 2008.

- E. Muljadi, Z. Mills, R. Foster, J. Conto, A. Ellis, " Fault Analysis at a Wind Power Plant for a One Year of Observation", presented at the IEEE Power Engineering Society, General Meeting, Pittsburgh, PA, July 20-24, 2008.

- E. Muljadi, S. Pasupulati, A. Ellis, D. Kosterev," Method of Equivalencing for a Large Wind Power Plant with Multiple Turbine Representation", presented at the IEEE Power Engineering Society, General Meeting, Pittsburgh, PA, July 20-24, 2008.

- IEEE Dynamic Performance of Wind Power Generation Task Force (DPWPGTF) "Tutorial on Wind Generation Modeling and Controls," IEEE PES General Meeting, Pittsburgh, PA, USA – July 22, 2008.

- WECC Power Flow Guidelines for Wind Power Plant, prepared by WECC-WGMG – 2008.

Future Research Projects

- In collaboration with WECC and wind turbine manufacturers, we plan to populate a WECC database with input parameters for dynamic models for turbines from different manufacturers.

- Wide area seasonal wind-power generation output assumptions.

- Presently, field data is very hard to get. In collaboration with WECC, wind plant owners, and operators, we plan to collect more data from the field.   Funding is needed to get good data from multiple wind power plants.